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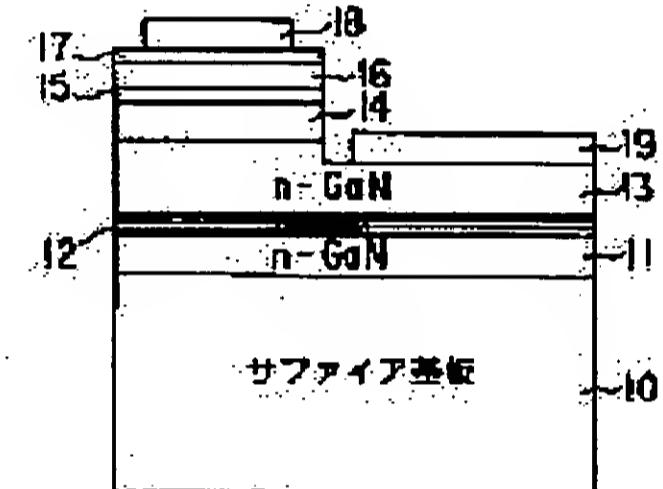
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(54) SEMICONDUCTOR ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To suppress the spread of the high density dislocation generated on the interface between a substrate and a growth layer to growth direction by a method wherein a cubic crystal distortion layer, having a substantial growth surface {111}, is provided between the growth substrate of a semiconductor element having an element part consisting of a hexagonal crystal semiconductor.

SOLUTION: A cubic crystal type n-GaN layer 11, having a growth surface, is formed on a sapphire substrate 10, and a distorted superlattice layer 12, on which an n-GaN layer and an n-HiGaN layer are alternately grown in critical film thickness or less, if formed thereon. An n-GaN layer 13, a clad layer 14, an active layer 15, a clad layer 16 and a contact layer 17 are successively grown thereon. Most of the dislocation of the high density generated by the lattice mismatching on the interface between the n-GaN layer 11 and the sapphire substrate 10 is changed its propagation direction by the distorted superlattice layer 12, and the propagation to the growth direction of transposition of high density generated on the interface between the substrate and the growth layer can be suppressed.



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CLAIMS

[Claim(s)]

[Claim 1] The semiconductor device characterized by preparing the distorted layer of the cubic mold which has a substantial {111} growth side between a growth substrate and said component section in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold.

[Claim 2] The semiconductor device characterized by preparing the strained layer superlattice of the cubic mold which has the substantial {111} growth side which includes the growth side which has less than 30 inclinations from {111} sides between a growth substrate and said component section in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the semiconductor device which consists of a compound semiconductor containing nitrogen, such as a semiconductor device especially GaN, AlGaN, and InGaN.

[0002]

[Description of the Prior Art] In order to aim at improvement in the recording density of an optical disk, and improvement in the resolution of a laser beam printer in recent years, the semiconductor laser (LD) in which luminescence with short wavelength is possible is demanded. As semiconductor laser of short wavelength, the property improvement also of which of reading of a disk and writing is carried out even at possible level, and 600nm band light source by the InGaAlP ingredient is already put in practical use. Aiming at the further improvement in recording density, development of blue semiconductor laser is performed briskly.

[0003] In such development, development to which the bluish green color semiconductor laser using the ZnSe system ingredient which is an II-VI group compound semiconductor has aimed at utilization, such as reinforcement and improvement in dependability, since oscillation actuation was checked is performed briskly.

[0004] However, by this ingredient system, it is becoming clear that the obstruction to utilization — the life from which the rearrangement produced according to the grid mismatching difference and coefficient-of-thermal-expansion difference between the substrate for growth and the growth phase which has the component section increases by energization, and dependability is not acquired is short — is expensive.

[0005] On the other hand, short-wavelengthizing is still more possible for GaN system semiconductor laser than a ZnSe system in ingredient, and also about dependability, since it is hardening in ingredient compared with a ZnSe system, it is expected as a promising ingredient. Although the rearrangement of 108 -1010cm⁻² exists by this ingredient system, the dependability of 10,000 hours or more is checked in LED, and researches and developments of the blue semiconductor laser which fulfills the conditions which need current for the next-generation optical disc system light source are done briskly.

[0006] By LED, existence of the rearrangement of 108 -1010cm⁻² does not pose a big problem as mentioned above. However, in LD which needs high current consistency impregnation, existence of the rearrangement of said high density of 108 -1010cm⁻² becomes the cause of reducing dependability.

[0007] By the way, the GaN system semiconductor device generally used as LED and LD now is formed on silicon on sapphire, and consists of a hexagonal mold (wurtzite mold) semi-conductor. Many results that the hexagonal mold of the crystal of a GaN system is more advantageous in respect of crystal quality as a GaN crystal for obtaining LED and the object for LD the place which is the former although a hexagonal mold and a cubic mold exist are reported.

[0008] Drawing 9 is the sectional view showing the outline structure of the conventional GaN system semiconductor device. The rearrangement in a hexagonal mold crystal is (101-0) (111-00) — expresses the in berth of 1., below the same — etc. — since it is the easiest to produce a skid on the cylindrical surface, the rearrangement of the high density of 108-1010cm⁻² produced by the grid mismatching between silicon on sapphire and a GaN layer as shown in drawing 9 spreads in the growth direction (a growth side and perpendicular direction), and penetrates to a front face to a barrier layer pan.

[0009] Therefore, since the rearrangement of the high density of 108 -1010cm⁻² exists in a barrier layer, crystallinity is bad, and it poses a problem that propagation of a rearrangement and growth arise by high current consistency impregnation in the case of LD etc., in order to reduce the dependability of a component.

[0010] In order to secure the dependability of GaN system semiconductor laser, it is important to reduce the consistency of the rearrangement generated in the interface of a substrate and a growth phase or not to make a barrier layer spread the rearrangement of the high density of 108 -1010cm⁻² which recognizes current existence.

[0011]

[Problem(s) to be Solved by the Invention] As mentioned above, in the semiconductor device of hexagonal molds including the conventional nitride system semiconductor device, since it is the easiest to spread the rearrangement generated in the interface of a substrate and a growth phase in the growth direction (a growth side and perpendicular direction), the rearrangement once produced in the interface will penetrate the component section as it is, and will escape from it on a growth phase front face. Especially in the case of the GaN system LD, the rearrangement of the high density of 108 -1010cm⁻² spread to the barrier layer which is a component core, and there was a problem of reducing the dependability of a component by high current consistency impregnation.

[0012] This invention was made in consideration of the above-mentioned situation, and aims at offering the semiconductor

device which can secure the dependability of a component by having structure which does not penetrate the rearrangement generated in the interface of a substrate and a growth phase to a component core (it is a barrier layer in the case of a light emitting device).

[0013]

[Means for Solving the Problem] In order to solve the above-mentioned technical problem, invention corresponding to claim 1 is the semiconductor device which prepared the distorted layer of the cubic mold which has a substantial {111} growth side between a growth substrate and the component section first in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold.

[0014] Next, invention corresponding to claim 2 is the semiconductor device which prepared the strained layer superlattice of the cubic mold which has a substantial {111} growth side including the growth side which has less than 30 inclinations from {111} sides between a growth substrate and the component section in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold.

(Operation) Thereby, according to the semiconductor device of invention corresponding to claim 1, the propagation to the growth direction of the rearrangement of the high density generated in the interface of a substrate and a growth phase can be first controlled by preparing the distorted layer of the cubic mold which has a {111} growth side in the lower part of the semiconductor device core of a hexagonal mold.

[0015] That is, when the rearrangement from a substrate reaches a distorted layer, most rearrangements fall out to a semiconductor device flank by the skid in the {111} sides which are a sliding surface of a cubic mold crystal.

[0016] Therefore, the dependability of a component is securable by having structure which does not penetrate the rearrangement generated in the interface of a substrate and a growth phase to a component core (it is a barrier layer in the case of a light emitting device).

[0017] In addition, although it may be a distorted layer of a monolayer, this distorted layer is much more effective, if a strained layer superlattice layer is used, for example. Next, in the semiconductor device of invention corresponding to claim 2, the growth side which has less than 30 inclinations from {111} sides, such as a {112} growth side and a {113} growth side, is included in the substantial {111} growth side. Even if there is an inclination of extent less than 30 degrees from {111} sides, it works enough and the above-mentioned derearrangement effectiveness by the skid in {111} sides acts like a semiconductor device according to claim 1.

[0018] In addition, as a means to solve the technical problem mentioned above, the following contents besides the above-mentioned means are also included.

(1) Said component section is a semiconductor device according to claim 1 or 2 characterized by consisting of a compound semiconductor containing nitrogen, such as GaN, AlGaN, and InGaN.

(2) It is the semiconductor device which is equipped with the semi-conductor layer of the cubic mold which has a substantial {111} growth side between a growth substrate and said component section in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold, and is characterized by being a mist straw paddle layer from other semi-conductor layers which the cubic type concerned of semi-conductor layer touches in said component section side.

(3) It is the semiconductor device which is equipped with the semi-conductor layer of the cubic mold which has a substantial {111} growth side between a growth substrate and said component section in the semiconductor device which has the component section which consists of a semi-conductor of a hexagonal mold, and is characterized by the cubic type concerned of semi-conductor layer being a layer harder than other semi-conductor layers which touch in said growth substrate side.

[0019] In addition, although the derearrangement effectiveness is fully acquired even when a monolayer is used as a semi-conductor layer of a cubic mold, as shown in the above (2) or (3), the case of the strained layer superlattice used combining the semi-conductor layer of each cubic mold in (2) and (3) can decrease a rearrangement most effectively.

[0020]

[Embodiment of the Invention] Hereafter, the operation gestalt of this invention is explained to a detail with reference to a drawing.

(Gestalt of implementation of the 1st of invention) Drawing 1 is the sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 1st operation gestalt of this invention.

[0021] In this semiconductor laser equipment, it is formed on silicon on sapphire 10. On silicon on sapphire 10, the n-GaN layer 11 (Si dope, 3-5x10¹⁸cm⁻³) of the cubic mold (sphalerite mold) which has a growth side first (111) is grown up at 650 degrees C by metal-organic chemical vapor deposition (MOCVD law).

[0022] The strained layer superlattice layer 12 (Si dope, 3-5x10¹⁸cm⁻³) which grows a n-GaN layer and a n-AlGaN layer by turns below by critical thickness on it is grown up at 650 degrees C. By making it grow up on the same conditions on the n-GaN layer 11 of the sphalerite mold which has a growth (111) side, this strained layer superlattice layer 12 turns into a strained layer superlattice layer of the sphalerite mold which has the same (111) growth side.

[0023] Next, the n-GaN layer 13 (an Si dope) which has a hexagonal mold (wurtzite mold) on the strained layer superlattice layer 12 by adjusting growth conditions 3-5x10¹⁸cm⁻³ is formed and it is the n-aluminum0.5 Ga0.5 N cladding layer 14 (an Si dope) of a wurtzite mold succeedingly. 5x10¹⁷cm⁻³ and 0.15 micrometers of thickness, the GaN barrier layer 15 (undoping) 0.1 micrometers of thickness, the p-aluminum0.5 Ga0.5 N cladding layer 16 (3 Mg dope, 0.15 micrometers of 5x10¹⁷cm⁻³ thickness), and the GaN contact layer 17 (3 Mg dope, 0.1 micrometers of one to 3x10¹⁸cm⁻³ thickness) are grown up at 1150 degrees C one by one. Here, control of the crystalline form to the wurtzite mold crystal from a sphalerite mold crystal is performed by control of the flow rate of the ammonia which is growth temperature and

hydrogen, nitrogen carrier gas, and a nitrogen raw material.

[0024] Moreover, although not illustrated especially, between the n-GaN layer 11 and silicon on sapphire 10, the AlN buffer layer which carried out low-temperature growth at 550 degrees C at the time of MOCVD growth is prepared.

[0025] Furthermore, the p lateral electrode 18 is formed in GaN contact layer 17 top face, and the n lateral electrode 19 is formed in the top-face part to which the laminating of the n-AlGaN cladding layer 14 on the n-GaN layer 13 is not carried out. Thus, the blue semiconductor laser equipment concerning this operation gestalt was obtained.

[0026] About the blue semiconductor laser equipment of the above-mentioned configuration, most rearrangements of the high density of 108 -1010cm⁻² generated by grid mismatching in the interface of silicon on sapphire 10 and the n-GaN layer 11 when the transmission electron microscope performed component observation from a cross section are changing propagation in the strained layer superlattice layer 12 prepared by this invention, and it was checked that the dislocation density in a barrier layer 15 is decreasing even to the 103 cm⁻³ set.

[0027] Thus, why dislocation density decreases is explained using drawing 2. Drawing 2 is a mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt.

[0028] When the rearrangement which spreads the inside of a semi-conductor tends to go into a hard semi-conductor layer relatively from a soft semi-conductor layer, advance of the rearrangement propagation will be obstructed and it will change the propagation direction. Drawing 2 showed this situation.

[0029] In the n-GaN layer and n-AlGaN layer which constitute the strained layer superlattice layer 12, it compares with a n-GaN layer and the n-AlGaN layer is a hard layer. Therefore, as shown in this drawing, a rearrangement 70 will change the propagation direction horizontally in the location which is going to go into a n-GaN layer from a n-AlGaN layer.

[0030] Specifically, that the sliding surface of a cubic mold crystal is a field (111) requires that modification of such a rearrangement propagation direction takes place. That is, by having formed the strained layer superlattice layer 12 which consists of the n-GaN layer and n-AlGaN layer of the sphalerite mold which has a growth (111) side between the substrate and the barrier layer Since it becomes the easiest to slide the field which is a sliding surface of a cubic mold crystal (111), and on a field parallel (111) to distortion to [of a strained layer superlattice] a growth side moreover on most rearrangements generated in the interface of silicon on sapphire 10 and the n-GaN layer 11, Propagation can be bent and it is thought that it escapes on the side face (the growth direction and perpendicular direction) of a component.

[0031] The dislocation density of the semi-conductor layer containing the barrier layer 15 after the n-GaN layer 13 which contains a barrier layer 15 by this as described above decreases sharply. Room temperature continuous oscillation of the semiconductor laser equipment produced as mentioned above was carried out with the threshold of 150mA. Oscillation wavelength was 365nm and operating voltage was 10V.

[0032] As mentioned above, according to the semiconductor device concerning the gestalt of operation of the 1st of this invention Since the propagation to the growth direction of the rearrangement of the high density which prepared the strained layer superlattice layer of the cubic mold which has a growth (111) side in the lower part of the semiconductor device core of a hexagonal mold etc., and was generated in the interface of a substrate and a growth side was controlled In the barrier layer section, even 103 cm⁻² can be decreased by the strained layer superlattice, and dependability can raise sharply the rearrangement of 108 -1010cm⁻² generated in the interface of a substrate and a growth phase in GaN system blue semiconductor laser.

[0033] That is, in the GaN system blue semiconductor laser of structure explained with the conventional technique, even if laser oscillation actuation was checked by existence of 108 -1010cm⁻² generated in the interface of a substrate and a growth phase to see laser oscillation was difficult, the dependability of a component was not acquired — a component is destroyed by high current consistency impregnation from the life of operation for several seconds or several minutes.

[0034] On the other hand, although the point that operating voltage was high remained as it was, in the above-mentioned semiconductor device produced according to the contents of this operation gestalt, the life of operation was prolonged by 100 to 1000 times over the past, and its dependability of a component improved sharply by it. (Gestalt of implementation of the 2nd of invention) as the 2nd operation gestalt — the 1st operation gestalt — the same — MOCVD — the blue semiconductor laser component which was produced by law and from which structure differs a little is explained.

[0035] Drawing 3 is the sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 2nd operation gestalt of this invention. In this GaN system blue semiconductor laser equipment, a GaN buffer layer (not shown) is prepared at 550-degree C low temperature on silicon on sapphire 20, and the n-GaN layer 21 (Si dope, 3-5x1018cm⁻³) of the cubic mold (sphalerite mold) which has a growth side first (111) like the case of the 1st operation gestalt on it is grown up at 750 degrees C.

[0036] Furthermore, the n-GaN/n-InGaN strained layer superlattice layer 22 (Si dope, 3-5x1018cm⁻³) of the sphalerite mold which has a growth side the same (111) on the n-GaN layer 21 is grown up at 750 degrees C.

[0037] Next, the n-GaN layer 23 (an Si dope) which has a hexagonal mold (wurtzite mold) 3-5x1018cm⁻³ is formed, and it continues, and is the n-aluminum0.5 Ga0.5 N cladding layer 24 (Si doping). 5x1017cm⁻³ and 0.3 micrometers of thickness, the GaN optical confinement layer 25 (undoping) 0.2 micrometers of thickness, the In0.1 Ga0.9 N multiplex quantum well barrier layer 26, the GaN optical confinement layer 27 (undoping) 0.2 micrometers of thickness, the p-aluminum0.5 Ga0.5 N cladding layer 28 (3 Mg dope, 0.3 micrometers of 5x1017cm⁻³ thickness), and the GaN contact layer 29 (3 Mg dope, 0.1 micrometers of one to 3x1018cm⁻³ thickness) are grown up at 1150 degrees C one by one.

[0038] Furthermore, the p lateral electrode 30 is formed in GaN contact layer 29 top face, and the n lateral electrode 31 is formed in the top-face part to which the laminating of the n-AlGaN cladding layer 24 on the n-GaN layer 23 is not carried out. Thus, the blue semiconductor laser equipment concerning this operation gestalt was obtained.

[0039] Also in this blue semiconductor laser equipment, the dislocation density of a barrier layer 26 was fully reduced. Next, oscillation actuation of the blue semiconductor laser equipment of the above-mentioned configuration is explained.

[0040] With the component of this structure, continuous oscillation was carried out to 50 degrees C with the threshold of 75mA. Oscillation wavelength checked 395nm by 7V, and operating voltage checked the operational stability by 5000 hours. Since the strained layer superlattice layer of the cubic mold which has a growth (111) side in the lower part of the semiconductor device core of a hexagonal mold etc. was prepared like the case of the 1st operation gestalt according to the semiconductor device concerning the gestalt of operation of the 2nd of this invention as mentioned above, the same effectiveness as the case of the 1st operation gestalt was acquired.

(Gestalt of implementation of the 3rd of invention) The case where the same GaN system semiconductor laser as the 1st and 2nd operation gestalt is formed as 3rd operation gestalt on the GaAs substrate which is the III-V group compound semiconductor of a cubic mold (sphalerite mold), and is widely used for the optical device, the electron device, etc. is explained.

[0041] Drawing 4 is the sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment formed on the GaAs substrate which applied the semiconductor device concerning the 3rd operation gestalt of this invention. In this GaN system blue semiconductor laser equipment, the n-GaN layer 41 (Si dope, 3-5x10¹⁸cm⁻³) of the cubic mold (sphalerite mold) which has a growth (111) side is first grown up at 550 degrees C by metal-organic chemical vapor deposition (MOCVD law) on the n-GaAs (111) substrate 40 of a cubic mold (sphalerite mold).

[0042] The strained layer superlattice layer 42 (Si dope, 3-5x10¹⁸cm⁻³) into which the n-GaN layer and the n-InGaN layer were grown up by turns below by critical thickness on it is formed. This strained layer superlattice layer 42 also serves as a sphalerite mold which has the same (111) growth side.

[0043] Next, in 750 degrees C, the flow rate of hydrogen, nitrogen carrier gas, and ammonia is changed. The n-GaN layer 43 (Si dope, 3-5x10¹⁸cm⁻³) which has a hexagonal mold (wurtzite mold) is formed. Then, the n-aluminum0.5 Ga0.5 N cladding layer 44 (an Si dope) of a wurtzite mold 5x10¹⁷cm - 3 and 0.2 micrometers of thickness, the In0.1 Ga0.9 N barrier layer 45 (undoping) 200A of thickness, the p-aluminum0.5 Ga0.5 N cladding layer 46 (3 Mg dope, 0.2 micrometers of 5x10¹⁷cm - thickness), and the GaN contact layer 47 (3 Mg dope, 0.1 micrometers of one to 3x10¹⁸cm - thickness) are grown up at 750 degrees C one by one.

[0044] The dependability of the double hetero structured division 51 as each class which consists of the n-GaN layer 43, the n-AlGaN layer 44, the InGaN barrier layer 45, a p-AlGaN layer 46, and a GaN contact layer 47 here, i.e., the component section, of a component property improves with constituting from a hexagonal mold more stable than a cubic mold.

[0045] moreover, SiO₂ constituted in this semiconductor laser equipment on the disk which has opening from — the becoming current constriction layer 48 is formed on the GaN contact layer 47, and the p lateral electrode 49 is formed so that it may contact the GaN contact layer 27 and directly through the above-mentioned opening further. On the other hand, the n lateral electrode 50 is formed in the n-GaAs substrate 20 bottom.

[0046] It was checked that most rearrangements produced in the interface of the GaAs substrate 40 and the n-GaN layer 41 could change propagation as a result of producing a skid on a growth (111) side by the strained layer superlattice layer 42 prepared in this operation gestalt, and it has fallen out on the component side face (the growth direction and perpendicular direction) like the case of the 1st operation gestalt about the blue semiconductor laser equipment of the above-mentioned configuration when a transmission electron microscope performs component observation from a cross section. The dislocation density in a barrier layer 45 was decreasing even to the 103 cm⁻³ set.

[0047] Next, oscillation actuation of the blue semiconductor laser equipment of the above-mentioned configuration is explained. Continuous oscillation of the semiconductor laser equipment which has the double hetero structure of this example was carried out to 80 degrees C with the threshold of 45mA. Oscillation wavelength checked 395nm by 4V, and operating voltage checked the operational stability by 7000 hours.

[0048] As mentioned above, according to the semiconductor device concerning the gestalt of operation of the 3rd of this invention Since the strained layer superlattice layer of the cubic mold which has a growth (111) side in the lower part of the semiconductor device core of a hexagonal mold etc. was prepared like the case of the 1st operation gestalt and also it enabled it to pass a current in the direction of a substrate, using the GaAs substrate 40 as a substrate The same effectiveness as the case of the gestalt of the 1st operation is acquired, and also it can make it low to improve in respect of component resistance, i.e., resistance, especially by this laser.

[0049] Although resistance becomes high in the case where an insulating substrate is used like the 1st operation gestalt like the conventional technique that is, since it becomes the method which pours in a current from a longitudinal direction, when a conductive substrate is used like this operation gestalt, it is possible to pass a current in the direction of a substrate, and component resistance is improved remarkably.

[0050] That is, conventionally, by the GaN system blue semiconductor laser of structure, most rearrangements of the high density generated in the interface of a substrate and a growth phase had spread to the InGaN barrier layer 45, with it being high resistance, the life of a component of operation is about several minutes, and dependability was not conjointly acquired by high current consistency impregnation for laser oscillation.

[0051] However, in the case of this operation gestalt, by the reduction in the dislocation density of a barrier layer 45, and low resistance-ization, the life of operation was prolonged by about 7000 times over the past, and the dependability of a component improved sharply.

(Gestalt of implementation of the 4th of invention) The gestalt of this operation shows the case where the distorted layer of a monolayer is used.

[0052] Drawing 5 is the sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 4th operation gestalt of this invention, gives the same sign to the same part as drawing 1 , and omits the explanation.

[0053] Replaced with the strained layer superlattice layer, and the InGaN layer 71 of a cubic mold was formed, and also this GaN system blue semiconductor laser equipment is constituted like the 1st operation gestalt. This InGaN layer 71 is compared with the n-GaN layer 13, it is a soft layer, by this, as shown in drawing 6, a rearrangement escapes from it, and the dislocation density of a barrier layer 15 is low.

[0054] Drawing 6 is a mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt. In this drawing, if the rearrangement 70 which spreads up the inside of the InGaN layer 71 which is a soft layer approaches the n-GaN layer 13 which is a hard layer, it will produce a skid on a growth (111) side, and can change the propagation direction, and the rearrangement 70 concerned will escape from a semiconductor device flank.

[0055] Since according to the semiconductor device concerning the gestalt of operation of the 4th of this invention it had the same configuration as the case of the 1st operation gestalt, and also it replaced with the strained layer superlattice layer and the InGaN layer 71 of a cubic mold was formed as mentioned above, low dislocation density-ization of a barrier layer can be attained like the case of the gestalt of the 1st operation.

(Gestalt of implementation of the 5th of invention) The gestalt of this operation shows the case where the distorted layer of a monolayer is used.

[0056] Drawing 7 is the sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 5th operation gestalt of this invention, gives the same sign to the same part as drawing 1, and omits the explanation.

[0057] Replaced with the strained layer superlattice layer, and the AlGaN layer 72 of a cubic mold was formed, and also this GaN system blue semiconductor laser equipment is constituted like the 1st operation gestalt. This AlGaN layer 72 is compared with the n-GaN layer 11, it is a hard layer, by this, as shown in drawing 8, a rearrangement escapes from it, and the dislocation density of a barrier layer 15 is low.

[0058] Drawing 8 is a mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt. In this drawing, if the rearrangement 70 which spreads up the inside of the n-GaN layer 11 which is a soft layer approaches the AlGaN layer 72 which is a hard layer, it will produce a skid on a growth (111) side, and can change the propagation direction, and the rearrangement 70 concerned will escape from a semiconductor device flank.

[0059] Since according to the semiconductor device concerning the gestalt of operation of the 5th of this invention it had the same configuration as the case of the 1st operation gestalt, and also it replaced with the strained layer superlattice layer and the AlGaN layer 72 of a cubic mold was formed as mentioned above, low dislocation density-ization of a barrier layer can be attained like the case of the gestalt of the 1st operation.

[0060] In addition, in each above-mentioned operation gestalt, although hexagonal mold silicon on sapphire and a cubic mold GaAs substrate were used as the substrate, this invention is not limited to this, and even when SiC, Si, ZnO, a spinel, neodium gallate (NdGaO₃, NGO), etc. are used as a substrate, it can be applied similarly.

[0061] Moreover, in the case of crystal growth like the above 1st, 2nd, 4th, and 5th operation gestalt, generally, the field (0001) of a sapphire substrate is used as a growth side, but this invention is not restricted to this and can use various fields, such as a field (011-2) of a sapphire substrate.

[0062] Furthermore, with each above-mentioned operation gestalt, in the case of a {111} growth side, the layer of a sake without [of the superlattice layers 12, 22, and 42, the InGaN layer 71, and AlGaN layer 72 grade] a rearrangement was explained, but this invention is not restricted in this case. For example, if it is the field which has the inclination of extent less than 30 degrees from {111} sides, such as {112} sides and {113} sides, the rearrangement omission effectiveness by the skid in the field which is a sliding surface of a cubic mold crystal (111) can fully be demonstrated, and, also in such a case, it is contained in the range of this invention. In addition, although (111) explained as an expression of the crystal face with each operation gestalt, it cannot be overemphasized that the same effectiveness can be acquired also by the case of {111}.

[0063] This invention can be applied not only to a semi-conductor light emitting device but to the electron device fields, such as a photo detector and a transistor, further again as a semi-conductor layer which has a hexagonal mold. in addition, in the range which is not limited to the gestalt of each above-mentioned implementation, and does not deviate from the summary, many things are boiled and this invention can be deformed

[0064]

[Effect of the Invention] Since according to this invention the semi-conductor layer of the cubic mold which has a growth (111) side in the lower part of the semi-conductor layer of a hexagonal mold is prepared and the propagation to the growth direction of a rearrangement was controlled as explained above, as the rearrangement generated in the interface of a substrate and a growth phase is not penetrated to a component core (it is a barrier layer in the case of a light emitting device), the semiconductor device which can secure the dependability of a component can be offered.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 1st operation gestalt of this invention.

[Drawing 2] The mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt.

[Drawing 3] The sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 2nd operation gestalt of this invention.

[Drawing 4] The sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment formed on the GaAs substrate which applied the semiconductor device concerning the 3rd operation gestalt of this invention.

[Drawing 5] The sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 4th operation gestalt of this invention.

[Drawing 6] The mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt.

[Drawing 7] The sectional view showing the outline configuration of the GaN system blue semiconductor laser equipment which applied the semiconductor device concerning the 5th operation gestalt of this invention.

[Drawing 8] The mimetic diagram explaining signs that a rearrangement falls out in the semiconductor device of this operation gestalt.

[Drawing 9] The sectional view showing the outline structure of the conventional GaN system semiconductor device.

[Description of Notations]

- 10 — Silicon on sapphire (hexagonal mold)
- 11 — Sphalerite mold n-GaN layer (crystal-defect consistency: about 108~1010cm⁻²)
- 12 — Sphalerite mold n-GaN/n-AlGaN strained layer superlattice layer
- 13 — Wurtzite mold n-GaN layer
- 14 — Wurtzite mold n-AlGaN cladding layer
- 15 — Wurtzite mold undoping GaN barrier layer
- 16 — Wurtzite mold p-AlGaN cladding layer
- 17 — Wurtzite mold p-GaN contact layer
- 18 — p lateral electrode
- 19 — n lateral electrode
- 20 — Silicon on sapphire (hexagonal mold)
- 21 — Sphalerite mold n-GaN layer (crystal-defect consistency: about 108~1010cm⁻²)
- 22 — Sphalerite mold n-GaN/n-InGaN strained layer superlattice layer
- 23 — Wurtzite mold n-GaN layer
- 24 — Wurtzite mold n-aluminum0.5 Ga0.5 N cladding layer
- 25 — Wurtzite mold GaN optical confinement layer
- 26 — Wurtzite mold In0.1 Ga0.9 N multiplex quantum well barrier layer
- 27 — Wurtzite mold GaN optical confinement layer
- 28 — Wurtzite mold p-aluminum0.5 Ga0.5 N cladding layer
- 29 — Wurtzite mold GaN contact layer
- 30 — p lateral electrode
- 31 — n lateral electrode
- 40 — GaAs (111) substrate (sphalerite mold)
- 41 — Sphalerite mold n-GaN layer
- 42 — Sphalerite mold n-InGaN/n-AlGaN strained layer superlattice layer
- 43 — Wurtzite mold n-GaN layer
- 44 — Wurtzite mold n-AlGaN cladding layer
- 45 — Wurtzite mold undoping InGaN barrier layer
- 46 — Wurtzite mold p-AlGaN cladding layer
- 47 — Wurtzite mold p-GaN contact layer
- 48 — Current constriction layer
- 49 — p lateral electrode

- 50 -- n lateral electrode
- 51 -- Double hetero structured division
- 71 -- Sphalerite mold InGaN layer
- 72 -- Sphalerite mold AlGaN layer

[Translation done.]

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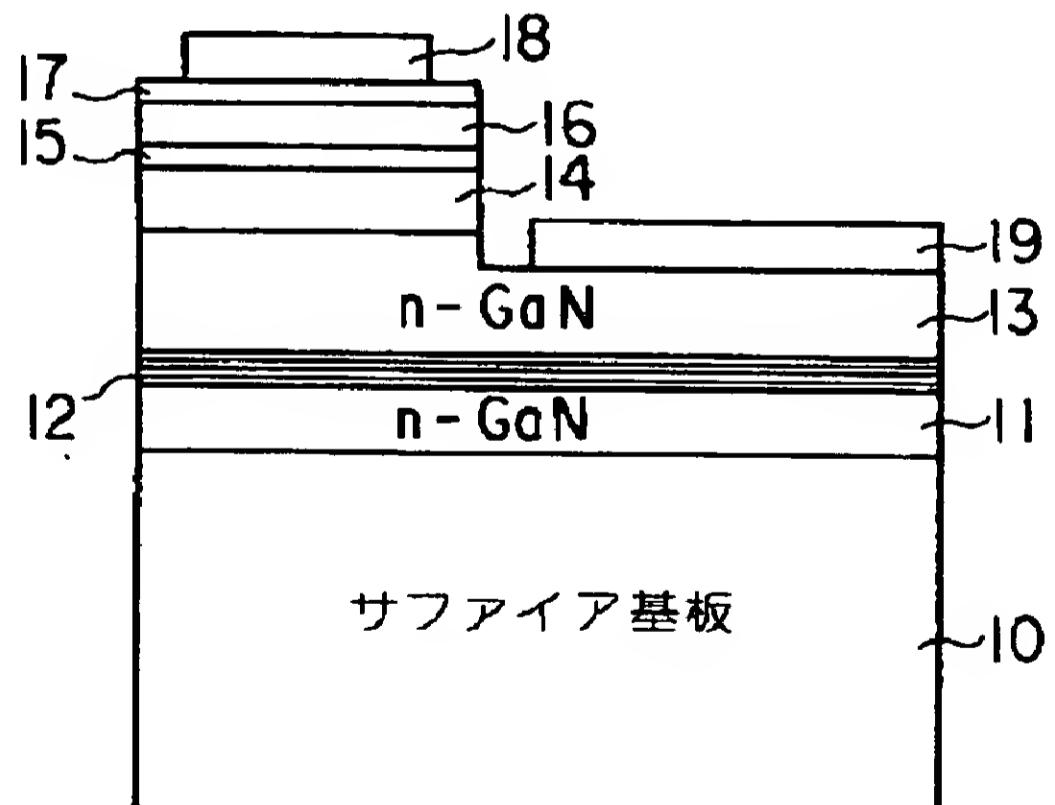
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(54) 【発明の名称】 半導体素子

(57) 【要約】

【課題】 六方晶型(ウルツ鉱型)半導体素子、例えばGaN系材料を用いた青色半導体レーザにおいて、転位伝播阻止による長寿命化、信頼性の向上を可能にする。

【解決手段】 六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と六方晶型の半導体からなる素子部との間に{111}成長面を有する立方晶型の歪超格子を設ける。これにより、半導体素子、特にGaN系青色半導体レーザにおいて、素子心臓部である活性層への転位伝播を抑制でき、素子の長寿命化、高信頼性化を実現できる。



【特許請求の範囲】

【請求項1】 六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と前記素子部との間に実質的な{111}成長面を有する立方晶型の歪層を設けたことを特徴とする半導体素子。

【請求項2】 六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と前記素子部との間に、{111}面から30度以内の傾斜を有する成長面を含む実質的な{111}成長面を有する立方晶型の歪超格子を設けたことを特徴とする半導体素子。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、半導体素子、特にGaN、AlGaN、InGaNなど窒素を含む化合物半導体からなる半導体素子に関するものである。

【0002】

【従来の技術】近年、光ディスクの記録密度の向上やレーザプリンタの解像度の向上を図るため、短波長での発光が可能な半導体レーザ(LD)が要求されている。短波長の半導体レーザとしてInGaAlP材料による600nm帯光源は、ディスクの読み込み、書き込みのどちらも可能なレベルにまで特性改善され、すでに実用化されている。さらなる記録密度向上を目指して青色半導体レーザの開発が盛んに行われている。

【0003】このような開発において、II-VI族化合物半導体であるZnSe系材料を用いた青緑色半導体レーザは発振動作が確認されて以来、長寿命化、信頼性向上など実用化を目指した開発が盛んに行われている。

【0004】しかし、この材料系では、成長用基板と素子部を有する成長層との間の格子不整合差や熱膨脹係数差により生じた転位が通電により増殖するなどして、信頼性が得られない、寿命が短いなど実用化への障壁は高いことが明らかになりつつある。

【0005】一方、GaN系半導体レーザは材料的にZnSe系よりもさらに短波長化が可能であり、信頼性に関する限りZnSe系に比べ材料的に硬化であるため有望な材料として期待されている。この材料系では $10^8 \sim 10^{10} \text{cm}^{-2}$ の転位が存在するが、LEDにおいては一万時間以上の信頼性が確認されており、現在は次世代の光ディスクシステム光源に必要な条件を満たす青色半導体レーザの研究開発が盛んに行われている。

【0006】上記のようにLEDでは $10^8 \sim 10^{10} \text{cm}^{-2}$ の転位の存在は大きな問題となっていない。しかし、大電流密度注入を必要とするLDでは、前記 $10^8 \sim 10^{10} \text{cm}^{-2}$ の高密度の転位の存在が信頼性を低下させる原因となる。

【0007】ところで、現在LED、LDとして一般に用いられているGaN系半導体素子はサファイア基板上に形成されており、六方晶型(ウルツ鉱型)半導体から成る。GaN系の結晶は六方晶型と立方晶型とが存在す

るが、これまでのところLED、LD用を得るためにGaN結晶としては、六方晶型の方が結晶品質の面で有利であるという結果が多く報告されている。

【0008】図9は従来のGaN系半導体素子の概略構造を示す断面図である。六方晶型結晶における転位は(101-0)、(11-00)(1-は1のインバースを表す。以下同じ)などの柱面上で最もすべりを生じやすいため、図9に示すようにサファイア基板とGaN層との間の格子不整合により生じた $10^8 \sim 10^{10} \text{cm}^{-2}$ の高密度の転位が、成長方向(成長面と垂直方向)に伝播し、活性層さらに表面まで貫通する。

【0009】したがって、活性層には $10^8 \sim 10^{10} \text{cm}^{-2}$ の高密度の転位が存在するため結晶性は悪く、LDの場合、大電流密度注入により転位の伝播、増殖が生じるなど、素子の信頼性を低下させるため問題となる。

【0010】GaN系半導体レーザの信頼性を確保するためには、基板と成長層の界面で発生する転位の密度を低減すること、または現在存在する $10^8 \sim 10^{10} \text{cm}^{-2}$ の高密度の転位を活性層に伝播させないことが重要である。

【0011】

【発明が解決しようとする課題】以上のように、従来の窒化物系半導体素子をはじめとする六方晶型の半導体素子では、基板と成長層との界面で発生した転位が成長方向(成長面と垂直方向)へ最も伝播しやすいため、一旦界面で生じた転位はそのまま素子部を貫通し、成長層表面にねることになる。特にGaN系LDの場合、素子心臓部である活性層に $10^8 \sim 10^{10} \text{cm}^{-2}$ の高密度の転位が伝播し、大電流密度注入により素子の信頼性を低下させるという問題があった。

【0012】本発明は上記事情を考慮してなされたもので、基板と成長層との界面で発生した転位を素子心臓部(発光素子の場合は活性層)へ貫通しないような構造を有することにより、素子の信頼性を確保できる半導体素子を提供することを目的とする。

【0013】

【課題を解決するための手段】上記課題を解決するためには、まず、請求項1に対応する発明は、六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と素子部との間に実質的な{111}成長面を有する立方晶型の歪層を設けた半導体素子である。

【0014】次に、請求項2に対応する発明は、六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と素子部との間に、{111}面から30度以内の傾斜を有する成長面を含む実質的な{111}成長面を有する立方晶型の歪超格子を設けた半導体素子である。

(作用)これにより、まず、請求項1に対応する発明の半導体素子によれば、六方晶型の半導体素子心臓部の下部に{111}成長面を有する立方晶型の歪層を設ける

ことにより、基板と成長層との界面で発生した高密度の転位の成長方向への伝播を抑制できる。

【0015】つまり、基板からの転位が、歪層に達したとき、立方晶型結晶のすべり面である{111}面でのすべりにより、転位の大部分が半導体素子側部に抜けるものである。

【0016】したがって、基板と成長層との界面で発生した転位を素子心臓部（発光素子の場合は活性層）へ貫通しないような構造を有することにより、素子の信頼性を確保できる。

【0017】なお、この歪層は単層の歪層であってもよいが、例えば歪超格子層を用いればより一層効果的である。次に、請求項2に対応する発明の半導体素子においては、実質的な{111}成長面には、{112}成長面や{113}成長面等の{111}面から30度以内の傾斜を有する成長面を含んでいる。{111}面から30度以内程度の傾斜があっても{111}面でのすべりによる上記した脱転位効果は十分働き、請求項1記載の半導体素子と同様に作用する。

【0018】なお、上述した課題を解決する手段としては、上記手段の他、以下の内容をも含む。

(1) 前記素子部はGaN、AlGaN、InGaN等の窒素を含む化合物半導体からなることを特徴とする請求項1又は2記載の半導体素子。

(2) 六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と前記素子部との間に実質的な{111}成長面を有する立方晶型の半導体層を備え、当該立方晶型の半導体層は前記素子部側にて接する他の半導体層よりもやわらかい層であることを特徴とする半導体素子。

(3) 六方晶型の半導体からなる素子部を有する半導体素子において、成長基板と前記素子部との間に実質的な{111}成長面を有する立方晶型の半導体層を備え、当該立方晶型の半導体層は前記成長基板側にて接する他の半導体層よりもかたい層であることを特徴とする半導体素子。

【0019】なお、上記(2)又は(3)のように立方晶型の半導体層として单層を用いた場合でも十分に脱転位効果は得られるが、(2)及び(3)における各立方晶型の半導体層を組み合わせて用いた歪超格子の場合が最も効果的に転位を減少させることができる。

【0020】

【発明の実施の形態】以下、本発明の実施形態について図面を参照して詳細に説明する。

(発明の第1の実施の形態) 図1は本発明の第1の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図である。

【0021】この半導体レーザ装置においては、サファイア基板10上に形成されている。サファイア基板10上には、有機金属気相成長法(MOCVD法)により、

まず(111)成長面を有する立方晶型(閃亜鉛鉱型)のn-GaN層11(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を650°Cで成長する。

【0022】その上にn-GaN層とn-AlGaN層を臨界膜厚以下で交互に成長する歪超格子層12(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を650°Cで成長する。この歪超格子層12は(111)成長面を有する閃亜鉛鉱型のn-GaN層11上に同一条件で成長させることにより、同様の(111)成長面を有する閃亜鉛鉱型の歪超格子層となる。

【0023】次に、成長条件を調整することによって歪超格子層12の上に六方晶型(ウルツ鉱型)を有するn-GaN層13(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を形成し、引き続いてウルツ鉱型のn-Al_{0.5}Ga_{0.5}Nクラッド層14(Siドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.15μm)、GaN活性層15(アンドープ、層厚0.1μm)、p-Al_{0.5}Ga_{0.5}Nクラッド層16(Mgドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.15μm)、GaNコンタクト層17(Mgドープ、 $1 \sim 3 \times 10^{18} \text{ cm}^{-3}$ 、層厚0.1μm)を順次1150°Cで成長させる。ここで、閃亜鉛鉱型結晶からウルツ鉱型結晶への結晶形態の制御は、成長温度、および水素、窒素キャリアガス、窒素原料であるアンモニアの流量比の制御により行われる。

【0024】また、特に図示しないが、n-GaN層11とサファイア基板10との間には、MOCVD成長時に550°Cで低温成長させたAlNバッファ層が設けられている。

【0025】さらに、GaNコンタクト層17上面には、p側電極18が設けられ、n-GaN層13上のn-AlGaNクラッド層14が積層されていない上面部分には、n側電極19が設けられる。このようにして本実施形態に係わる青色半導体レーザ装置が得られた。

【0026】上記構成の青色半導体レーザ装置について、透過電子顕微鏡により断面からの素子観察を行ったところ、サファイア基板10とn-GaN層11との界面で格子不整合により発生した $10^8 \sim 10^{10} \text{ cm}^{-2}$ の高密度の転位の大部分が、本発明により設けた歪超格子層12で伝播方向を変えており、活性層15における転位密度は 10^3 cm^{-3} 台にまで減少していることが確認された。

【0027】このように転位密度が減少する理由について図2を用いて説明する。図2は本実施形態の半導体素子において転位が抜ける様子を説明する模式図である。

【0028】半導体中を伝搬する転位は、やわらかい半導体層から相対的にかたい半導体層に入ろうとするとき、その転位伝搬の進行が阻まれ、伝搬方向を変えることになる。この様子を示したのが図2である。

【0029】歪超格子層12を構成するn-GaN層とn-AlGaN層とでは、n-GaN層に比しn-Al

GaN層がかたい層となっている。したがって、同図に示すように、n-AlGaN層からn-GaN層に入ろうとする位置で、転位70は水平方向にその伝搬方向を変えることになる。

【0030】具体的には、このような転位伝搬方向の変更が起こるのは、立方晶型結晶のすべり面が(111)面であることによっている。つまり、(111)成長面を有する閃亜鉛鉱型のn-GaN層とn-AlGaN層から成る歪超格子層12を基板と活性層の間に設けたことにより、サファイア基板10とn-GaN層11との界面で発生した転位の大部分が、立方晶型結晶のすべり面である(111)面、しかも歪超格子の歪み方向から成長面と平行な(111)面上で最も滑りやすくなるため、伝播方向を曲げられ素子の側面(成長方向と垂直方向)に抜けると考えられる。

【0031】これにより、上記したように活性層15を含むn-GaN層13以降の活性層15を含む半導体層の転位密度は大幅に減少する。以上のように作製した半導体レーザ装置は、しきい値150mAで室温連続発振した。発振波長は365nm、動作電圧は10Vであった。

【0032】上述したように、本発明の第1の実施の形態に係わる半導体素子によれば、六方晶型の半導体素子心臓部の下部に(111)成長面を有する立方晶型の歪超格子層等を設け、基板と成長面との界面で発生した高密度の転位の成長方向への伝播を抑制するようにしたので、GaN系青色半導体レーザにおいては基板と成長層との界面で発生した $10^8 \sim 10^{10} \text{ cm}^{-2}$ の転位を歪超格子により活性層部では 10^3 cm^{-2} にまで減少させることができ、信頼性が大幅に向上去ることができる。

【0033】すなわち従来技術で説明した構造のGaN系青色半導体レーザでは、基板と成長層との界面で発生した $10^8 \sim 10^{10} \text{ cm}^{-2}$ の存在により、レーザ発振が困難であるか、レーザ発振動作が確認されても大電流密度注入により数秒ないしは数分の動作寿命で素子が破壊されるなど、素子の信頼性が得られていなかった。

【0034】これに対し、本実施形態の内容に従い作製した上述の半導体素子では、動作電圧が高い点はそのままであるにかかわらず、動作寿命が従来の100~1000倍に延び、素子の信頼性が大幅に向上了。(発明の第2の実施の形態) 第2の実施形態として、第1の実施形態と同様、MOCVD法により作製したやや構造の異なる青色半導体レーザ素子について説明する。

【0035】図3は本発明の第2の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図である。このGaN系青色半導体レーザ装置においては、サファイア基板20上に550°Cの低温でGaNバッファ層(図示せず)を設け、その上に第1の実施形態の場合と同様に、まず(111)成長面を有する立方晶型(閃亜鉛鉱型)のn-GaN層21

(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を750°Cで成長させる。

【0036】さらに、n-GaN層21上に、同じく(111)成長面を有する閃亜鉛鉱型のn-GaN/n-InGaN歪超格子層22(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を750°Cで成長させる。

【0037】次に、六方晶型(ウルツ鉱型)を有するn-GaN層23(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を形成し、続いてn-Al_{0.5}Ga_{0.5}Nクラッド層24(Siドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.3μm)、GaN光閉じ込め層25(アンドープ、層厚0.2μm)、In_{0.1}Ga_{0.9}N多重量子井戸活性層26、GaN光閉じ込め層27(アンドープ、層厚0.2μm)、p-Al_{0.5}Ga_{0.5}Nクラッド層28(Mgドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.3μm)、GaNコンタクト層29(Mgドープ、 $1 \sim 3 \times 10^{18} \text{ cm}^{-3}$ 、層厚0.1μm)を順次1150°Cで成長させる。

【0038】さらに、GaNコンタクト層29上面には、p側電極30が設けられ、n-GaN層23上のn-AlGaNクラッド層24が積層されていない上面部分には、n側電極31が設けられる。このようにして本実施形態に係わる青色半導体レーザ装置が得られた。

【0039】この青色半導体レーザ装置においても活性層26の転位密度は十分に低減された。次に、上記構成の青色半導体レーザ装置の発振動作を説明する。

【0040】本構造の素子ではしきい値75mAで50°Cまで連続発振した。発振波長は395nm、動作電圧は7Vで5000時間までの安定動作を確認した。上述したように、本発明の第2の実施の形態に係わる半導体素子によれば、第1の実施形態の場合と同様に、六方晶型の半導体素子心臓部の下部に(111)成長面を有する立方晶型の歪超格子層等を設けたので、第1の実施形態の場合と同様な効果が得られた。

(発明の第3の実施の形態) 第3の実施形態として、第1、第2の実施形態と同様のGaN系半導体レーザを、立方晶型(閃亜鉛鉱型)のIII-V族化合物半導体であって、光デバイス、電子デバイス等に広く利用されているGaN基板上に形成する場合について説明する。

【0041】図4は本発明の第3の実施形態に係る半導体素子を適用したGaN基板上に形成したGaN系青色半導体レーザ装置の概略構成を示す断面図である。このGaN系青色半導体レーザ装置においては、立方晶型(閃亜鉛鉱型)のn-GaN(111)基板40上に、有機金属気相成長法(MOCVD法)により、まず、(111)成長面を有する立方晶型(閃亜鉛鉱型)のn-GaN層41(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を550°Cで成長させる。

【0042】その上にn-GaN層とn-InGaN層を臨界膜厚以下で交互に成長させた歪超格子層42(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を設ける。この歪超格

子層42も同様の(111)成長面を有する閃亜鉛鉱型となる。

【0043】次に750°Cにおいて、水素、窒素キャリアガスおよびアンモニアの流量を変更し、六方晶型(ウルツ鉱型)を有するn-GaN層43(Siドープ、 $3 \sim 5 \times 10^{18} \text{ cm}^{-3}$)を形成し、続いてウルツ鉱型のn-A_{1.5}Ga_{0.5}Nクラッド層44(Siドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.2μm)、In_{0.1}Ga_{0.9}N活性層45(アンドープ、層厚200オングストローム)、p-A_{1.5}Ga_{0.5}Nクラッド層46(Mgドープ、 $5 \times 10^{17} \text{ cm}^{-3}$ 、層厚0.2μm)、GaNコンタクト層47(Mgドープ、 $1 \sim 3 \times 10^{18} \text{ cm}^{-3}$ 、層厚0.1μm)を順次750°Cで成長させる。

【0044】ここでn-GaN層43、n-A₁GaN層44、InGaN活性層45、p-A₁GaN層46、GaNコンタクト層47からなる各層、すなわち素子部としてのダブルヘテロ構造部51は立方晶型よりも安定である六方晶型で構成することで素子特性の信頼性が向上する。

【0045】また、この半導体レーザ装置においては、開口を有する円板上に構成されたSiO₂からなる電流狭窄層48がGaNコンタクト層47の上に設けられ、さらに上記開口を介してGaNコンタクト層27と直接接触するようにp側電極49が設けられている。一方、n-GaAs基板20の下側にはn側電極50が設けられている。

【0046】上記構成の青色半導体レーザ装置について、透過電子顕微鏡により断面からの素子観察を行ったところ、第1の実施形態の場合と同様、GaAs基板40とn-GaN層41との界面で生じた転位の大部分が、本実施形態において設けた歪超格子層42により(111)成長面上ですべりを生じた結果伝播方向を変えられ、素子側面(成長方向と垂直方向)にぬけていることが確認された。活性層45における転位密度は 10^3 cm^{-2} 台にまで減少していた。

【0047】次に、上記構成の青色半導体レーザ装置の発振動作について説明する。本実施例のダブルヘテロ構造を有する半導体レーザ装置は、しきい値4.5mAで80°Cまで連続発振した。発振波長は395nm、動作電圧は4Vで7000時間までの安定動作を確認した。

【0048】上述したように、本発明の第3の実施の形態に係わる半導体素子によれば、第1の実施形態の場合と同様に、六方晶型の半導体素子心臓部の下部に(111)成長面を有する立方晶型の歪超格子層等を設けた他、基板としてGaAs基板40を用い、基板方向に電流を流せるようにしたので、第1の実施の形態の場合と同様な効果が得られる他、本レーザでは特に素子抵抗の面で改善をすること、すなわち抵抗値を低くすることができる。

【0049】従来技術と同様に、つまり第1の実施形態

のように絶縁性基板を用いた場合には、横方向から電流を注入する方式になるために抵抗は高くなるが、本実施形態のように導電性基板を用いた場合は基板方向に電流を流すことが可能であり、著しく素子抵抗が改善される。

【0050】つまり、従来構造のGaN系青色半導体レーザでは、基板と成長層との界面で発生した高密度の転位の大部分がInGaN活性層45まで伝播しており、レーザ発振のための大電流密度注入により、高抵抗であることと相俟って、素子の動作寿命は数分程度であり信頼性が得られなかった。

【0051】しかし、本実施形態の場合は、活性層45の低転位密度化、低抵抗化により、動作寿命が従来の約7000倍に延び、素子の信頼性が大幅に向上了。

(発明の第4の実施の形態) 本実施の形態は、単層の歪層を用いた場合を示すものである。

【0052】図5は本発明の第4の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図であり、図1と同一部分には同一符号を付してその説明を省略する。

【0053】このGaN系青色半導体レーザ装置は、歪超格子層に代えて立方晶型のInGaN層71を設けた他、第1の実施形態と同様に構成されている。このInGaN層71は、n-GaN層13に比し、やわらかい層であり、これにより、図6に示すように転位が抜け、活性層15の転位密度は低くなっている。

【0054】図6は本実施形態の半導体素子において転位が抜けた様子を説明する模式図である。同図において、やわらかい層であるInGaN層71内を上方に伝搬する転位70は、かたい層であるn-GaN層13に近づくと、(111)成長面上ですべりを生じてその伝搬方向を変えられ、当該転位70は半導体素子側部から抜けた。

【0055】上述したように、本発明の第4の実施の形態に係わる半導体素子によれば、第1の実施形態の場合と同様の構成を有する他、歪超格子層に代えて立方晶型のInGaN層71を設けたので、第1の実施の形態の場合と同様、活性層の低転位密度化を図ることができる。

(発明の第5の実施の形態) 本実施の形態は、単層の歪層を用いた場合を示すものである。

【0056】図7は本発明の第5の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図であり、図1と同一部分には同一符号を付してその説明を省略する。

【0057】このGaN系青色半導体レーザ装置は、歪超格子層に代えて立方晶型のAlGaN層72を設けた他、第1の実施形態と同様に構成されている。このAlGaN層72は、n-GaN層11に比し、かたい層であり、これにより、図8に示すように転位が抜け、活性

層15の転位密度は低くなっている。

【0058】図8は本実施形態の半導体素子において転位が抜ける様子を説明する模式図である。同図において、やわらかい層であるn-GaN層11内を上方に伝搬する転位70は、かたい層であるAlGaN層72に近づくと、(111)成長面上ですべりを生じてその伝搬方向を変えられ、当該転位70は半導体素子側部から抜ける。

【0059】上述したように、本発明の第5の実施の形態に係る半導体素子によれば、第1の実施形態の場合と同様の構成を有する他、歪超格子層に代えて立方晶型のAlGaN層72を設けたので、第1の実施の形態の場合と同様、活性層の低転位密度化を図ることができると。

【0060】なお、上記各実施形態においては、六方晶型サファイア基板、立方晶型GaN基板をその基板として用いたが、本発明はこれに限定されるものではなく、SiC、Si、ZnO、スピネル、ネオジウムガレート(NdGaO_3 、NGO)等を基板とした場合でも同様に適用が可能である。

【0061】また、上記第1、第2、第4、第5の実施形態のような結晶成長の場合、一般的にはサファイア基板の(0001)面が成長面として用いられるが、本発明はこれに限られるものではなく、例えばサファイア基板の(011-2)面等の種々の面を用いることができる。

【0062】さらに、上記各実施形態では、超格子層12、22、42、InGaN層71、AlGaN層72等の転位抜きのための層を(111)成長面の場合で説明したが、本発明はこの場合に限られるものではない。例えば(112)面や(113)面等の(111)面から30度以内程度の傾斜を有する面であれば、立方晶型結晶のすべり面である(111)面でのすべりによる転位抜け効果は十分に發揮でき、このような場合も本発明の範囲に含まれる。なお、各実施形態では結晶面の表現として(111)で説明したが、(111)の場合でも同様な効果を得られることはいうまでもない。

【0063】さらにまた、本発明は、六方晶型を有する半導体層として、半導体発光素子のみならず、受光素子、トランジスター等の電子デバイス分野へも適用が可能である。なお、本発明は、上記各実施の形態に限定されるものではなく、その要旨を逸脱しない範囲で種々に変形することが可能である。

【0064】

【発明の効果】以上説明したように、本発明によれば、六方晶型の半導体層の下部に(111)成長面を有する立方晶型の半導体層を設けて転位の成長方向への伝播を抑制するようにしたので、基板と成長層との界面で発生した転位を素子心臓部(発光素子の場合は活性層)へ貫通しないようにして、素子の信頼性を確保できる半導体

素子を提供することができる。

【図面の簡単な説明】

【図1】本発明の第1の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図。

【図2】同実施形態の半導体素子において転位が抜ける様子を説明する模式図。

【図3】本発明の第2の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図。

【図4】本発明の第3の実施形態に係る半導体素子を適用したGaN基板上に形成したGaN系青色半導体レーザ装置の概略構成を示す断面図。

【図5】本発明の第4の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図。

【図6】同実施形態の半導体素子において転位が抜ける様子を説明する模式図。

【図7】本発明の第5の実施形態に係る半導体素子を適用したGaN系青色半導体レーザ装置の概略構成を示す断面図。

【図8】同実施形態の半導体素子において転位が抜ける様子を説明する模式図。

【図9】従来のGaN系半導体素子の概略構造を示す断面図。

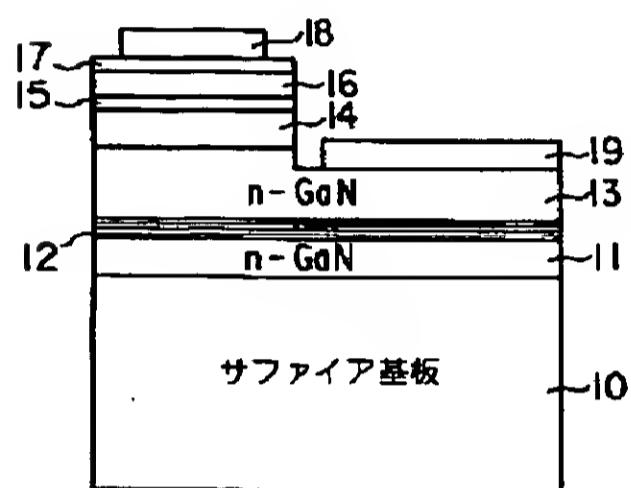
【符号の説明】

- 10…サファイア基板(六方晶型)
- 11…閃亜鉛鉱型n-GaN層(結晶欠陥密度:約 $10^8 \sim 10^{10} \text{ cm}^{-2}$)
- 12…閃亜鉛鉱型n-GaN/n-AlGaN歪超格子層
- 13…ウルツ鉱型n-GaN層
- 14…ウルツ鉱型n-AlGaNクラッド層
- 15…ウルツ鉱型アンドープGaN活性層
- 16…ウルツ鉱型p-AlGaNクラッド層
- 17…ウルツ鉱型p-GaNコンタクト層
- 18…p側電極
- 19…n側電極
- 20…サファイア基板(六方晶型)
- 21…閃亜鉛鉱型n-GaN層(結晶欠陥密度:約 $10^8 \sim 10^{10} \text{ cm}^{-2}$)
- 22…閃亜鉛鉱型n-GaN/n-InGaN歪超格子層
- 23…ウルツ鉱型n-GaN層
- 24…ウルツ鉱型n-Al_{0.5}Ga_{0.5}Nクラッド層
- 25…ウルツ鉱型GaN光閉じ込め層
- 26…ウルツ鉱型In_{0.1}Ga_{0.9}N多重量子井戸活性層
- 27…ウルツ鉱型GaN光閉じ込め層
- 28…ウルツ鉱型p-Al_{0.5}Ga_{0.5}Nクラッド層

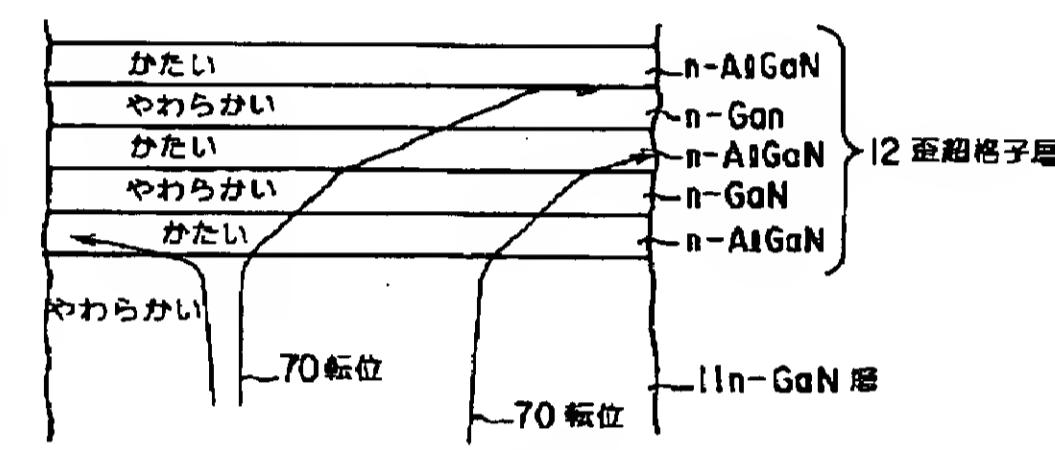
29…ウルツ鉱型GaNコンタクト層
 30…p側電極
 31…n側電極
 40…GaAs(111)基板(閃亜鉛鉱型)
 41…閃亜鉛鉱型n-GaN層
 42…閃亜鉛鉱型n-InGaN/n-AlGaN歪超格子層
 43…ウルツ鉱型n-GaN層
 44…ウルツ鉱型n-AlGaNクラッド層

45…ウルツ鉱型アンドープInGaN活性層
 46…ウルツ鉱型p-AlGaNクラッド層
 47…ウルツ鉱型p-GaNコンタクト層
 48…電流狭窄層
 49…p側電極
 50…n側電極
 51…ダブルヘテロ構造部
 71…閃亜鉛鉱型InGaN層
 72…閃亜鉛鉱型AlGaN層

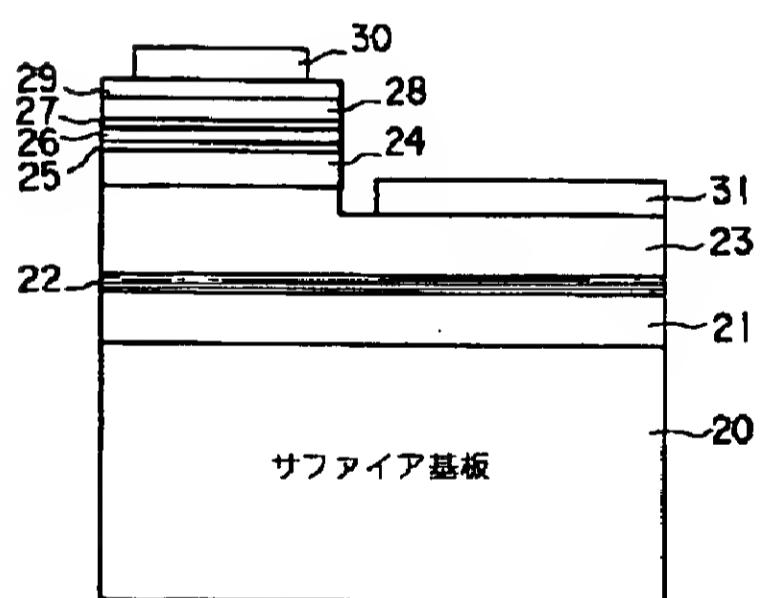
【図1】



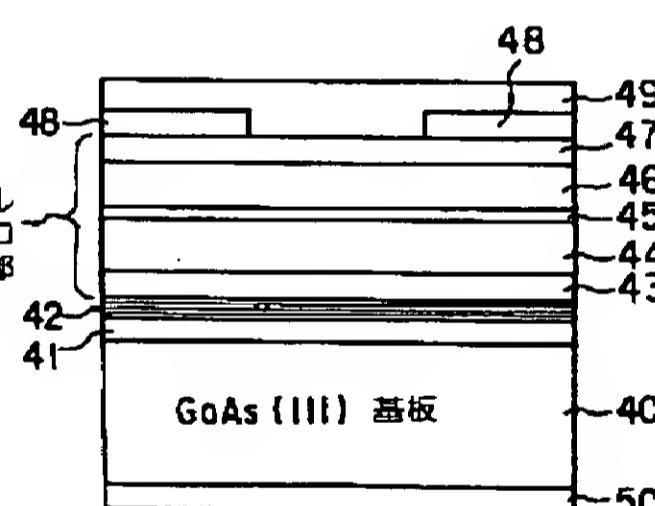
【図2】



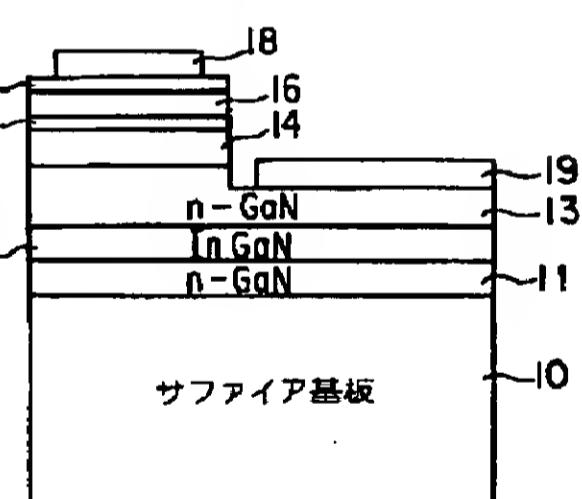
【図3】



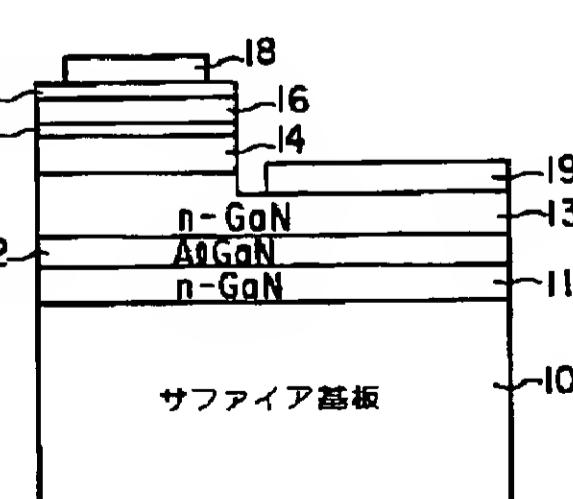
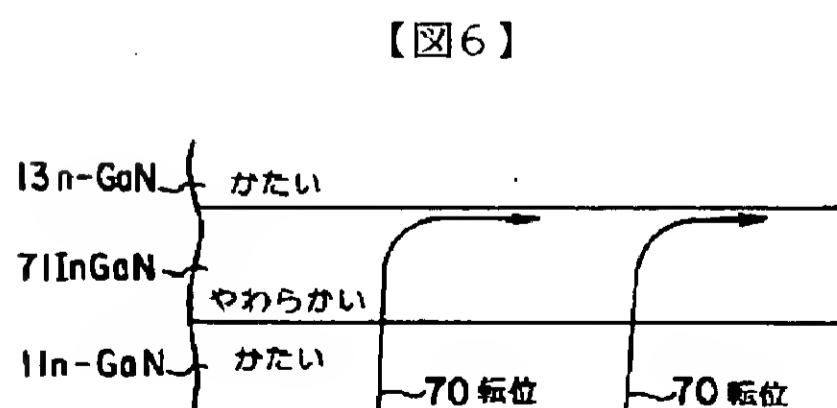
【図4】



【図5】

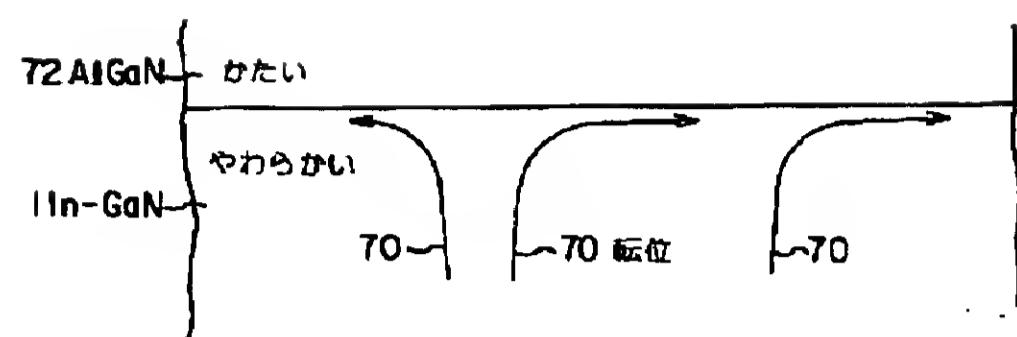


【図7】



【図6】

【図8】



【図9】

